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(54) Title of the Invention: Signal Transmission Method for Mobile Communication

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SPECIFICATION

1. Title of the Invention

Signal transmission method for mobile communication

2. Claims

(1) A signal transmission method for mobile communication wherein:

the mobile station transmission and the base station transmission have the same frequency;

time division is performed so that said mobile station transmission and said base station transmission are performed in alternating time slots;

reception quality at the mobile station (or base station) is detected; and

when said detected reception quality drops below a predetermined value, the transmission of information signal from the mobile station (or the base station) during the time slot following the time slot [when the drop in reception quality below the predetermined value was detected] is stopped or the transmission is performed after changing to a modulation method of a higher reliability.

(2) The signal transmission for mobile communication according to claim 1 wherein the transmission time slot of said base station is synchronized for a plurality of channels.

(3) The signal transmission for mobile communication according to claim 1 wherein said mobile station (or base station) controls its transmission power according to its reception level.

(4) The signal transmission for mobile communication according to claim 1 wherein the directionality of the antenna of the mobile station is changeable in the horizontal plane, [said antenna] detects the direction in the horizontal plane that maximizes the reception quality, and performs a transmission in the detected directionality during the next transmission time slot.

3. Detailed Description of the Invention

Field of Industrial Use

The present invention relates to a method of signal transmission of a high reliability over a mobile communication transmission path where fading occurs at the reception level.

Prior Art

With mobile communication and, in particular, with terrestrial mobile transmission, because of the general lack of a direct line of sight between the mobile station and the base station, the reception level is the product of the synthesis of direct waves and multiple reflected waves that are reflected by buildings and the like. This

results in a fading that is close to a Rayleigh distribution. A Rayleigh distribution is a deep fading where the level is 20 to 30 dB less than the average value, causing a significant reduction in the reliability of the signal transmission.

FIG. 4 shows an example of a signal transmission property with and without fading (Institute of Electronics, Information and Communication Engineers, "Digital Transmission Technology in Mobile Communication," Figure 6, February 1982). Without fading, the error is almost non-existent so long as the reception input level is more than 0 dBμ. With fading, errors increase significantly. When fading is present, errors occur in a concentrated manner as the reception level decreases due to fading.

To solve these problems, the use of error correction codes, ARQ and the like have been discussed in the prior art, but none of these methods provides a fundamental solution to signal errors that occur as [the reception] level is reduced by fading.

Means for Solving the Problems

With the present invention, when the reception quality, for example, reception level, is reduced by fading, the signal transmission is stopped or the modulation method is changed to a more reliable method – such as reducing the signal transmission speed during that time only. By so doing, signal errors during periods of low reception quality is eliminated.

To explain, with the present invention, the mobile station transmission and the base station transmission have the same frequency; time division is performed using periods that are sufficiently short against fading so that the mobile station transmission and the base station transmission are performed in alternating time slots; reception quality at the mobile station (or base station) is detected; and when the detected reception quality drops below a predetermined value, the transmission of information signal from the mobile station (or the base station) during the time slot following the time slot [when the drop in reception quality below the predetermined value was detected] is stopped or the transmission is performed after changing to a modulation method of a higher reliability.

Because the period of the time slots is sufficiently short in duration than the duration of the fading, the present invention makes use of the fact that the reception quality at the base station (or the mobile station) is roughly equal to the reception quality by the mobile station (or the base station) of the signals that are transmitted by the base station (or the mobile station) during the next time slot. In this way, with the present invention, because a transmission path with fading is used for signal transmission only when the reception quality is high, the signal transmission reliability that is achieved becomes close to what it would be without fading.

Furthermore, at the base station, the transmission time slots are synchronized for a plurality of channels, in particular for adjacent channels to prevent the effects of blocking caused by signal infiltration.

Said synchronization of transmission time slots among a plurality of channels at the base station is performed across adjacent zones as well to prevent mobile stations located near zone boundaries from being affected by the effects of blocking.

The mobile station (or base station) detects the reception level and controls the transmission power according to the reception level. For example, if the reception level is higher than a reference value, the transmission power is reduced by a value that

corresponds to the amount of the difference so that the transmission power is kept to the necessary minimum.

An antenna whose directionality in the horizontal plane can be changed is used at the mobile station. The direction in the horizontal plane that maximizes the reception quality is detected, and transmission is performed in the detected direction during the next transmission time slot.

Embodiments

FIG. 1 shows an embodiment of the present invention. At base station 10, when the signal transmission conditions further described below are met, its information signal is provided via signal input line 11 to controller 12 and then via signal output line 13 to transmitter 14 which modulates the carrier wave and transmits the signal to the mobile station 17 via transmission/reception separator 15 and antenna 17 [sic].

During the reception timing of base station 11 [sic] which is the transmission timing of mobile station 17, a control signal from controller 12 travels via transmitter on/off control signal line 18 and turns off the transmission by transmitter 14.

At mobile station 17, the transmitted signal from the base station 10 is received by receiver 22 via antenna 19 and transmission/reception separator 22. The signal is demodulated and is provided to controller 24 via signal output line 23. At the same time, an information indicating the reception level is provided by receiver 22 to controller 24 via reception level information line 25.

Controller 24 determines whether the demodulated signal includes a signal that carries information from the base station 10. If such signal is present, the information signal is output via signal output line 26. At the same time, controller 24 also uses the information coming over the reception level information line 25 to determine whether or not the reception level is equal to or above a predetermined value. If [the reception level] is not equal to or above the predetermined value, the output of the information signal to signal output line 27 is stopped.

The foregoing was a description of what happens when the base station is transmitting and the mobile station is receiving. The operation is the same for transmission by the mobile station and reception by the base station. At base station 10, receiver 28 is connected to transmission/reception separator 15. Signal output line 29 and reception level information line 31 coming from receiver 28 are connected to controller 12. Signal output line 32 used to output the reception information signal from the mobile station is connected to controller 12. At the mobile station 17, transmitter 33 is connected to transmission/reception separator 21. Transmitter 33 is connected by control signal line 34 to controller 24 which controls the turning on and off of the transmission. Signal input line 35 which carries the information signal to be sent to the base station is connected to controller 24.

The carrier waves for transmitter 14 at the base station and transmitter 33 at the mobile station use the same frequency, and their transmissions occur at alternating time slots, i.e., using the time division method. When this is done, the controller 12 of the base station acts as the master, and controller 24 operates in synchrony with the control provided by controller 12.

FIG. 2 shows an example of a specific configuration of controller 12. The same numerical references are used for the same parts as in FIG. 1. The demodulated signal

from receiver 28 is supplied via signal output line 29 to synchronization identification circuit 41 where bit synchronization, code identification, frame synchronization and the like are performed. The signal is then supplied to and temporarily stored by buffer circuit 43 via identification signal output line 42. However, if the demodulated signal from receiver 28 does not include the information signal from mobile station 17, no signal is output to the identification signal output line 42.

On the other hand, the information signal from base station 10 is temporarily supplied to buffer circuit 44 via signal input line 11. The reception level information from receiver 28 is supplied via reception level information line 31 to signal transmission/reception control circuit 45 where a decision is made as to whether or not the reception level exceeds a predetermined value. If the reception level is less than the predetermined value, signal read control line 46 is used to stop the reading of the signal from buffer circuit 44 to signal output line 13 during the next time slot for transmission by the base station. If the reception level exceeds the predetermined value, the signal is read from buffer circuit 44 to signal output line 13 starting from the oldest information signal. The signal transmission/reception control circuit 45 generates the timings for base station transmission and mobile station transmission and uses the transmitter on/off control signal line 18 to control transmitter 14 so that it is turned off during the time slots for transmission by the mobile station. Controller 24 is similarly configured as controller 12 and operates similarly.

The manner in which signals are transmitted depending on the reception level is described next with reference to FIG. 3. Curve 51 represents a continuous representation of the reception levels for the alternating receptions by the base station and the mobile station. Because the transmissions by base station 10 and mobile station 17 occur at the same frequency, the waveform of curve 51 is equal to the waveform of the reception levels for a continuous transmission by base station 10 or mobile station 17. The transmission time slots for base station 10 are identified by 52, and the transmission time slots for mobile station 17 are identified by 53. In time slots 52 and 53, the hatchings identify the time slots during which information signals are actually transmitted as packets from the base station or the mobile station. Where [the time slots] are only outlined in black identifies the time slots where an information signal is not transmitted. For example, to send a signal [at a rate] of 10 kb/s with a terrestrial mobile communication method in the 800 MHz band, since the fading speed is, at the most, several dozen Hz or so, a time slot with a length of several ms and individual packets with a size of several dozen bits are used to transmit the signals.

Since the reception level 51 exceeds threshold value E_S for both the base station 10 and the mobile station 17 until time slot T_1, signal packets are alternately sent until time slot T_1. At time slot T_1, base station 10 receives the transmission packet from the mobile station. At the next time slot T_2, the base station 10 transmits a packet. However, since this is received by mobile station 17 with a reception level that is less than the threshold level E_S, mobile station 17 does not transmit an information signal at the next time slot T_3, instead transmitting only the carrier wave. Since the carrier wave is received by base station 10 with a reception level that is less than the threshold value E_S, the base station 10 does not transmit an information signal at the next time slot T_4, instead transmitting only the carrier wave. Subsequently, only carrier waves are alternately transmitted until time slot T_i. At time slot T_i, only the carrier wave is received

by base station 10 from mobile station 17. However, since the reception level exceeds the threshold value E_S, the base station 10 transmits the information signal at the next time slot, T_{i+1}. Subsequently, the information signals are alternately transmitted until the reception levels by the base station or the mobile station drops below the threshold value E_S.

In the foregoing description, when the reception level decreases, only unmodulated carrier waves are transmitted, but it is also possible to modulate the carrier waves using a signal of a different pattern that indicates that no information signals are included. Furthermore, in the afore-description, when the reception level dropped below a threshold value E_S, the transmission of the information signal was stopped. It is possible instead to change to a modulation method of a higher reliability. Specifically, the bit rate can be reduced to increase reliability, or in the case of an FSK, the frequency shifting can be increased, etc. to improve reliability. Since this means that signals are transmitted at a high speed when the reception level is high, and if the signal level is low, the signal speed, etc. is dropped to the point that sufficient signal reliability is obtained, a highly efficient signal transmission becomes possible.

In the afore-description, whether or not the reception level was above the predetermined value E_S was used as a decision criteria for sending the information signal or changing the modulation method, but if error correction codes and the like are used, the error rate or the presence or absence of errors in the signal may be used as the decision criteria. Or, the degree of clock jitter in the reception signal, the degree of opening of the eye pattern, demodulation noise levels outside the signal band, etc. can be used as the decision criteria. In other words, the reception quality is used as the decision criteria.

An embodiment of the present invention for a more efficient use of the afore-described invention is described next.

A first example is described next. With the first example, the afore-described signal transmission/reception control is used as the basis for synchronizing the transmission/reception over a plurality of channels. Because the transmission/reception frequencies are the same for every channel, if a plurality of channels is assigned to the base station, the signal infiltration level to adjacent channels and the like when transmission is taking place at a certain channel becomes very high. This may result in reception to become impossible in adjacent channels and the like due to blocking and the like. To avoid this, for the base station channels where said blocking and the like are a concern, the transmission timings (time slots) are synchronized. This means that the reception timings are also synchronized. In general, since a controller that controls the channels is disposed in a base station, the transmission timings among said channels can be easily synchronized.

Furthermore, adjacent wireless zones are set up with partial overlaps among them. If a mobile station is located in an overlapping area, the signal from an adjacent zone may cause blocking and the like. If this is a concern, the transmission timings (time slots) are synchronized among adjacent zone channels. This synchronization can be easily performed by the control station that manages a plurality of base stations.

A second example is described next. With the second example, the afore-described control for signal transmission/reception is used as the basis to control the transmission power. To explain, since the transmission/reception frequencies are the

same, the reception level of a station is approximately equal to the reception level of the counterpart station. Hence, the difference between the reception level of the station and a predetermined level that is set in advance is detected. If the reception level [of the station] is higher, the transmission power for the transmission is reduced by an amount equivalent to the difference. If said difference is negative, the transmission power is increased. By so doing, the instantaneous value of the reception level at the counterpart station becomes approximately equal to the set level. This allows the transmission power to be suppressed to the minimum necessary value, thus minimizing the amount of interference to others.

A third example is described next. With the third example, an antenna whose directionality in the horizontal plane is variable is used in the mobile station so that transmission is performed in the direction of the maximum reception level. With a terrestrial mobile communication, received waves by a mobile station are a synthesis of direct waves and waves that are reflected and diffracted by nearby buildings. The angle of arrival of these waves is random. Fading will be significantly improved if only one or a few of said waves are received. To realize this, antennas 51 through 54 with a 90° directionality is arranged as shown in FIG.5 with a 90° offset among the antennas. The outputs of each antenna 51 through 54 are compared by level comparator 55 so that the antenna whose reception is at the maximum level is selected by switch 56. In a system such as this, even during a timing for the transmission by a mobile station, the transmission occurs while preserving the position that was selected by switch 56 during the immediately previous reception timing. Since the transmission/reception frequencies are the same, the reception level of a base station that is receiving is going to be high just like the reception by a mobile station.

The way in which the directionality in the horizontal plane is changed is not limited to the afore-described method of switching the antennas. The directionality may also be changed by varying the feeding phase of a plurality of antennas. Furthermore, even though there was a description of performing a transmission in a direction that maximized the reception level, any direction that maximizes the reception quality will work such as the direction that minimizes the reception clock jitter or maximizes the reception eye pattern. Furthermore, since the change in the direction of maximum reception quality is slow, the periods used for detecting the maximum reception quality can be long. Furthermore, taking into account the thinness of fading, it is possible to calculate an average of the detected reception qualities in different directions and to select a direction that maximizes the average value.

Effects of the Invention

As afore-described, with the present invention, the transmission and reception are performed at the same frequency. When the reception quality is low, transmission is stopped at the next time slot or a modulation method of a higher reliability is used, thus eliminating or sufficiently reducing signal errors that are caused by reduced reception levels that occur with fading and providing an information signal transmission of a high reliability that is close to what can be achieved in the absence of fading. The amount of drop in signal transmission efficiency that accompanies these measures is very low as explained below. For example, in FIG. 4, the error rate in the absence of fading increases

dramatically at ranges below 0 dbμ. Also, for an average reception input of 20 dbμ where fading is present, errors occur when the instantaneous reception level becomes less than 0 dbμ. Therefore, even if the signal transmission is stopped when the instantaneous reception level is less than 0 dbμ, the percentage of time [that the instantaneous reception level is less than 0 dbμ] in a Rayleigh distribution is only approximately 1%.

Also, in the first example of the afore-described embodiments, blocking caused by the infiltration of transmission/reception in the presence of a plurality of channels for each base station can be avoided. With the second example, the instantaneous reception level at the counterpart station can be kept roughly constant, thus minimizing the amount of interference to others. With the third example, the reception quality at a mobile station can be improved while improving the reception quality at a base station.

4. Brief Description of the Figures

FIG. 1 is a block diagram showing an example of the configuration of the present invention. FIG. 2 is a block diagram showing an example of the configuration of controller 12 shown in FIG. 1. FIG. 3 shows an example of the reception level and signal transmission by the base station and the mobile station. FIG. 4 shows an example of the signal transmission properties with and without fading. FIG. 5 is a block diagram showing an example of an apparatus for varying the directionality of a mobile station.

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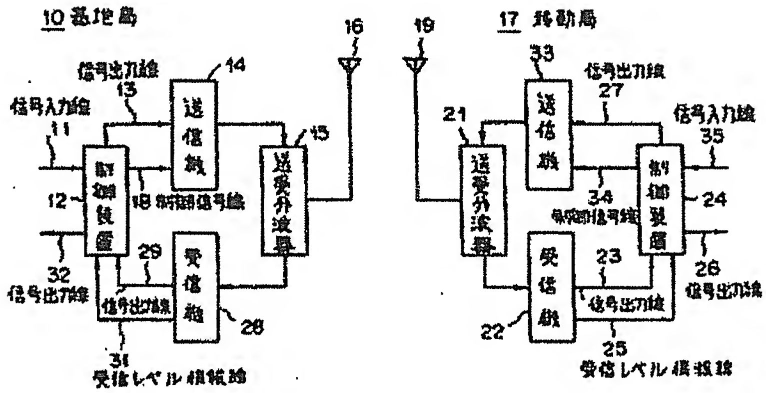
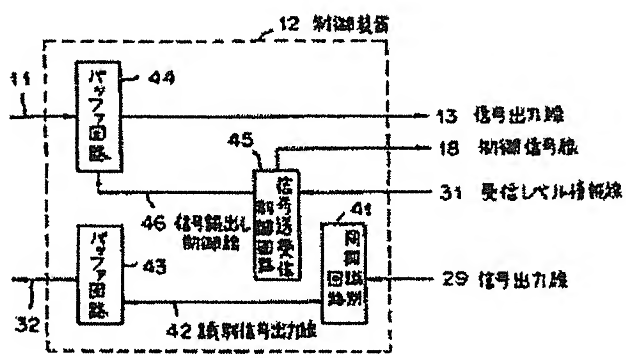
FIG. 1



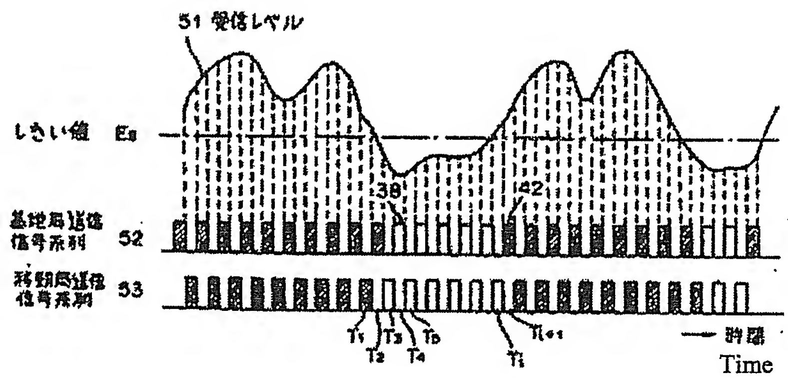
10. Base station
11. Signal input line
12. Controller
13. Signal output line
14. Transmitter
15. Transmission/ reception separator
17. Mobile station
18. Control signal line
21. Transmission/ reception separator
22. Receiver
23. Signal output line
24. Controller
25. Reception level information line
26. Signal output line
27. Signal output line
28. Receiver
29. Signal output line
31. Reception level information line
32. Signal output line

FIG. 2



12. Controller
13. Signal output line
18. Control signal line
29. Signal output line
31. Reception level information line
43. Buffer circuit
44. Buffer circuit
45. Signal transmission/ reception control circuit
46. Signal read control line

FIG. 3



E_S: Threshold value
51. Reception level
52. Base station transmission signal sequence
53. Mobile station transmission signal sequence

FIG. 4

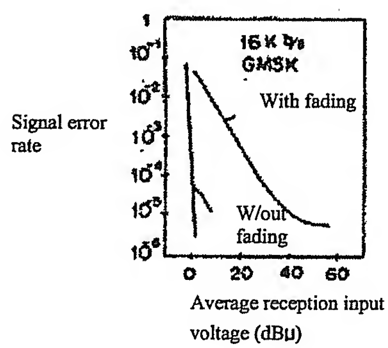
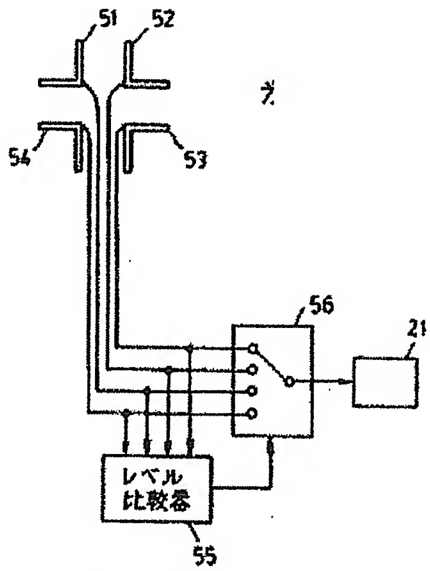


FIG. 5



55. Level comparator